PROCESS DEBOTTLENECKING OF SMALL SCALE LIQUEFIED NATURAL GAS (LNG) PLANT

NURUL AIN BINTI RAMLI

A report submitted in partial fulfillment of the requirement for the award of the degree of Bachelor of Chemical Engineering (Gas Technology)

Faculty of Chemical and Natural Resources Engineering
Universiti Malaysia Pahang

APRIL 2009

I declare that this thesis entitled "Process Debottlenecking of Small Scale Liquefied Natural Gas (LNG) Plant" is the result of my own research except as cited in references. This thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

Signature	:	……………………………………
Name of Candidate	:	Nurul Ain Binti Ramli
Date	:	……………………………………

“To my beloved mother and father, family and someone special who gave me encouragement toward this study”

ACKNOWLEDGEMENTS

I would like to express my gratefulness to Allah S.W.T for giving me strength and wisdom in my research work. In preparing this thesis, I was contact with many people, researcher, academicians, technicians and practitioners. They all have contributed to my understanding and valuable thoughts during my research. First and foremost, I would like to express my special thanks to my supervisor, Mr. Abdul Halim Bin Abdul Razik, for her encouragement, guidance, ideas which enlighten my curiosity, suggestion, advice and friendship. I am grateful to my fellow collogues who also should be recognized for their moral support. Their view and tips are useful indeed, but it is not possible to list them all in this limited space. Finally, I am deeply indebt to my parents, Ramli Ibrahim and Norihan Kamarudin, who always gave their advice, spirit, and encouragement to me in completing my educational drive.

ABSTRACT

Process debottlenecking is one of a process improvement and particularly important when the current conditions of a plant reaches maximum production rate without satisfying market demands. In the case of liquefied natural gas (LNG), transcontinental demands always show steady increment. Since LNG is a source of clean energy and a feedstock to chemical productions, process debottlenecking of existing LNG plants offers economic benefits. In this research, the first objective was to perform process debottlenecking of a published flow sheet of a small scale LNG plant by using Aspen HYSYS. “Bottlenecks” or unit operations which reach bottlenecked conditions were identified by increasing the inlet flow rate. Simulation results showed that, LNG heat exchanger 2 was the single bottlenecked unit operations identified due to the occurrence of temperature cross. The bottlenecks removal was then performed by transferring duty of this active bottleneck to an additional cooler installed. Five different modifications were designed which installation of a cooler at different stream in the flow sheet and applied. Modification 5 showed the highest percentage of LNG production with 5298.68% increment from the existing plant. Production revenue for this modification is RM 2552098.60 after takes into consideration the highest cost of its additional cooling duty which is RM 400000.00. General economic benefits for this work need to be further analyzed so that the importance of process debottlenecking of LNG plant become more comprehensive.

ABSTRAK

Proses menyingkirkan gangguan terhadap sesuatu kerja adalah salah satu proses kemajuan dan penting pada masa kini terutamanya apabila hasil pengeluaran tertinggi tidak memenuhi kehendak pasaran. Merujuk kepada kes Gas Asli Cecair, bahan ini selalunya menunjukkan permintaan yang memberangsangkan di seluruh dunia. Memandangkan Gas Asli Cecair adalah sumber tenaga yang bersih dan keperluan bagi produksi kimia, proses ini menawarkan kelebihan daripada segi ekonomi. Penyelidikan ini mempunyai dua objektif. Objektif pertama adalah untuk melakukan proses penyingkiran gangguan pada kertas kajian loji Gas Asli Cecair skala kecil menggunakan kaedah simulasi melalui pengsimulasi Aspen HYSYS. Unit operasi yang mengalami masalah akan dikenalpasti melalui kaedah menaikkan kadar pengaliran awal sesuatu proses. Hasil simulasi memunjukkan bahawa alat penukaran haba yang kedua adalah unit operasi yang mengalami gangguan melalui pengecaman ketika berlakunya perselisihan suhu. Proses penyingkiran ini akan melibatkan pemindahan duti pada unit operasi yang mengalami gangguan kepada alat penyejuk tambahan. Terdapat lima modifikasi yang telah dilakukan dan diaplikasi melalui penambahan bahan penyejuk pada aliran yang berbeza. Modifikasi kelima menunjukkan hasil pengeluaran yang tertinggi iaitu kenaikan sebanyak 5298.68% daripada loji asal. Hasil pengeluaran untuk modifikasi ini adalah RM 2552098.60 selepas melalui pertimbangan pembelian alat penyejuk tambahan iaitu RM 400000.00. Analis ekonomi bagi penyelidikan ini dicadangkan dianalis secara lebih telus lagi supaya kepentingan proses ini dapat dilihat secara lebih menyeluruh.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 World LNG Trading

Natural Gas demand is expected to increase nearly 40% from 22 Trillion cubic feet to 31 Trillion cubic feet between 2002 and 2025. (National Energy Technology, Future Supply and Emerging Resources Liquefied Natural Gas). According to the Energy Information Administration, world natural gas consumption and production are expected to increase by more than 50 percent from 2005 through 2030. Asia is expected to become the world's number one gas consumer, taking over that spot from North America, as China's economy grows 6.4 percent annually. Non-Organization for Economic Co-operation and Development (OECD) countries are expected to account for more than 70 percent of the world's total growth in consumption and production of natural gas over the forecast period. A significant portion of the non-OECD production growth is expected to be in the form of export projects, particularly LNG projects. World LNG trade is projected to more than double by 2030, with the center of the trade moving away from northeast Asia toward an even Atlantic/Pacific basin split. Figure 1.1 shows us the world natural gas reserves by geographic region and Figure 1.2 illustrates the world natural gas production.

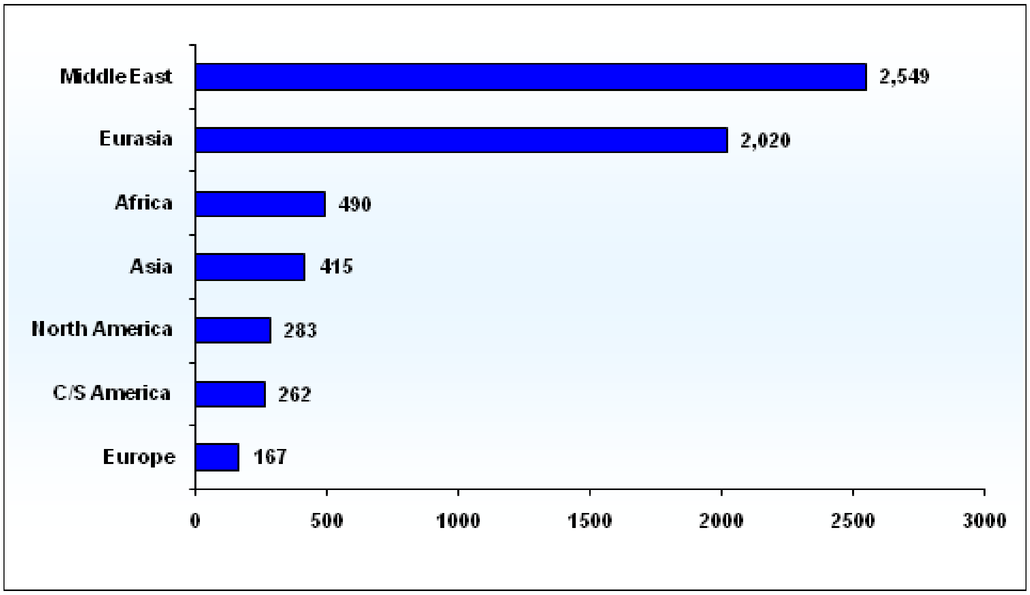

Figure 1.1: World Natural Gas Reserves by Geographic Region as of January 1, 2008, Sources: Energy Information Administration (EIA), Oil & Gas Journal, Vol. 105, No. 48 (December 24, 2007), pp. 24-25.

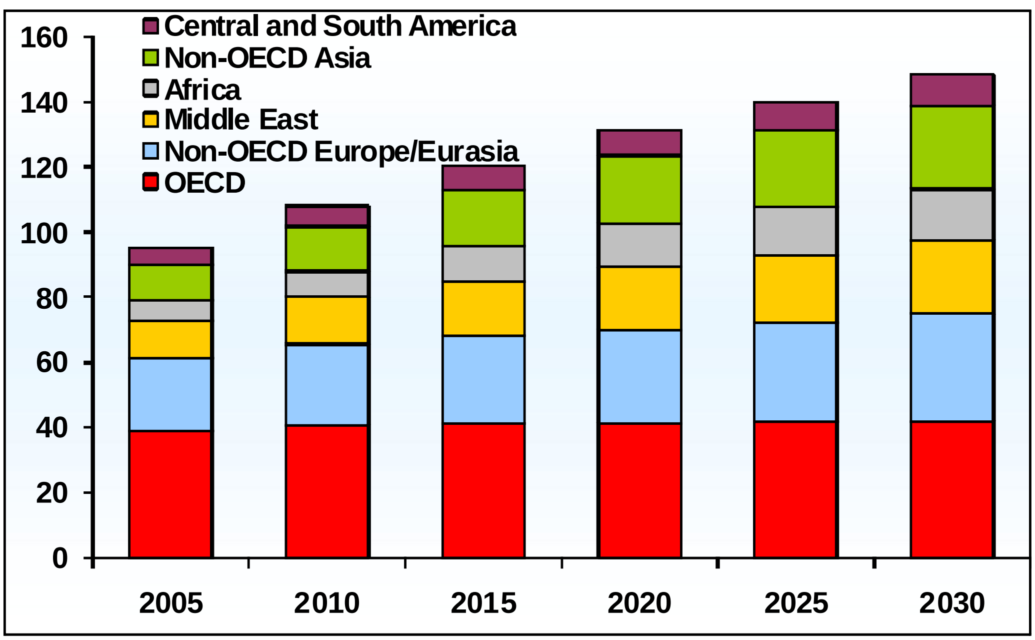

Figure 1.2: World Natural Gas Production (Trillion Cubic Feet), Sources: Energy Information Administration (EIA), International Energy Outlook 2008.

The efficient and effective movement of natural gas from producing regions to consumption regions requires an extensive and elaborate transportation system. In many instances, natural gas produced from a particular well will have to travel a great distance to reach its point of use. The transportation system for natural gas consists of a complex network of pipelines, designed to quickly and efficiently transport natural gas from its origin, to areas of high natural gas demand.

Generally, the limitations of the supply natural gas because of the above complexities can be solved by converting the phase of natural gas to become liquid, known as liquefied natural gas (LNG). By having LNG, the volume of natural gas can be reduced by about 600-fold which make it can be stored and transported in a huge amount compared to pipeline. It is also more economical to transport between continents in specially designed ocean vessel, whereas traditional pipeline transportation system would be less economically attractive and could be technically and politically infeasible. On the other hand, because transportation of natural gas is closely linked to its storage, then, liquefaction of natural gas provides the greatest opportunity to store natural gas for use during high demand periods in area where geologic conditions are not suitable for developing underground storage facilities. For example, in the northeastern part of United States, which is a region lacking in underground storage; LNG is a critical part of the region's supply during cold snaps. On the other hand, in region where pipelines capacity from supply area can be very expensive and use is highly seasonal, liquefaction and storage of LNG occurs during off-peak periods in order to reduce expensive capacity commitments during peak-periods. From the above discussion, we can conclude that LNG technology makes natural gas available throughout the world.

Liquefied natural gas is a natural gas that has been liquefied or converted to liquid form by reducing the temperature below -161 ^{0}C (260 ^{0}F) at 1 atm. Liquefied natural gas is primarily methane, nature's simplest and most abundant hydrocarbon fuel. Methane is composed of one carbon and four hydrocarbon atom (CH_4). LNG gas takes up about 1/600 th the volume of natural gas at store burner tip. It is odorless, colorless, non-toxic, non-corrosive and clear fluid which is less than half the density of water (roughly 0.41 to 0.5 kg/L, depending on temperature, pressure and composition, compared to water at 1.0 kg/L). The liquefaction process involves of certain components, such as dust, helium, and heavy hydrocarbons, which could causes difficulty downstream. Then gas is sent to a liquefaction plant where additional processing removes the remaining water vapor and carbon dioxide from the gas. A refrigeration process turns it into a liquid and further purities the stream so that LNG is predominantly methane. It also contains small amounts of ethane, propane, butane and heavier alkanes. The purification process can be designed to give almost absolutely methane (Hoegh, LNG articles).

Natural gas and its component are used as fuel for generating electricity and as raw material to manufacture a wide variety of products, from fibers for clothing, to plastic for healthcare, computing, and furnishing. Besides being used as the power generation plants, for feed to chemical plants, LNG is also a very promising fuel for aero planes, new generation rockets and ground vehicles, either as direct fuel for engines or as fuel for fuel cells (Liu and You, 1999).

1.2 Natural Liquefaction Process

Liquefaction is carried out at a pressure determined by economics factors and generally accomplished in the range of temperature between -116 ^{0}C to 161 ^{0}C at near atmospheric pressure (Fischer-Calderon, 2003). A higher pressure reduces the energy required to liquefy the natural gas, since the temperature range during the liquefaction process rises, although the final sub cooling temperature remains unchanged. Natural gas is liquefied over a temperature interval owing to the presence of hydrocarbons other than methane. The initial liquefaction temperature is higher with increasing contents of heavy hydrocarbons. For instance, it may begin at around -10 ^{0}C and continue to a temperature close to the vapor-liquid equilibrium temperature of methane under pressure, around -100 ^{0}C. The liquid phase obtained is then sub cooled to the boiling point of LNG at atmospheric pressure.

1.2.1 Types of Natural Liquefaction Process

1.2.1.1 Cascade Process

The cascade produces LNG by employing several closed-loop discrete cooling circuits or stages. Each circuits is utilizing pure refrigerant and collectively configured in order of progressively lower temperatures and generally have multistage refrigerant expansion and compression, typically operating at different evaporation temperature levels. The first cooling circuit may utilize propane, the second circuit utilizes ethane, and the third circuit utilizes methane as the refrigerant. After compression, propane is condensed with cooling water/air, ethane is condensed with evaporating propane and methane is condensed with evaporating ethane. Figure 1.3 shows The Simplified Cascade Process in LNG Production (From CPI, 2006).

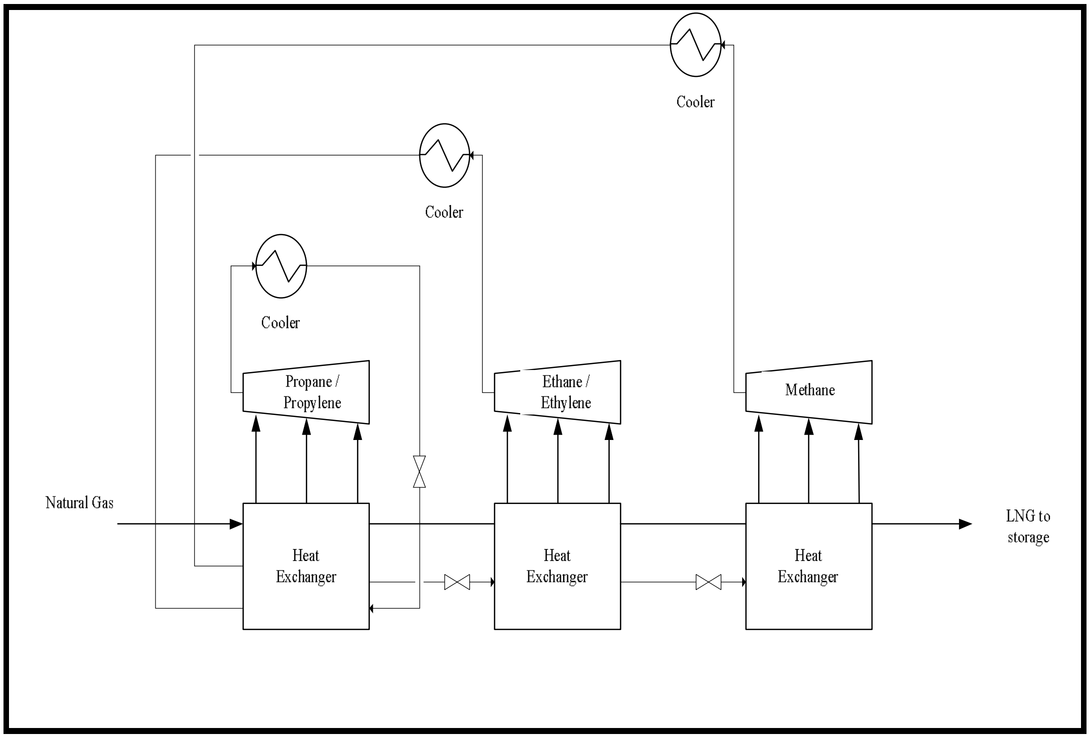

Figure 1.3: The Simplified Cascade Process in LNG Production (From CPI, 2006)

1.2.1.2 Single Mixed Refrigerant Process

A mixture of component having different volatilities, such as nitrogen, methane, ethane, propane and butane, is vaporized, by following in the enthalpy-temperature diagram a path of parallel to the one followed by the natural gas. This helps to liquefy the natural gas in a single mixed-refrigerant modified cascade cycle. In this cycle, the vaporization of a portion the liquid fractions obtained at increasingly lower temperatures serves to continue the condensation of the refrigerant mixture. The incorporation of the nitrogen makes it possible to sub cool to -160^{0}C, and thus avoid the loss of “flashed” gas by expansion, which occurs in the conventional cascade process. Figure 1.4 shows The Simplified Single Mixed Refrigerant Process (From Lee, 2000).

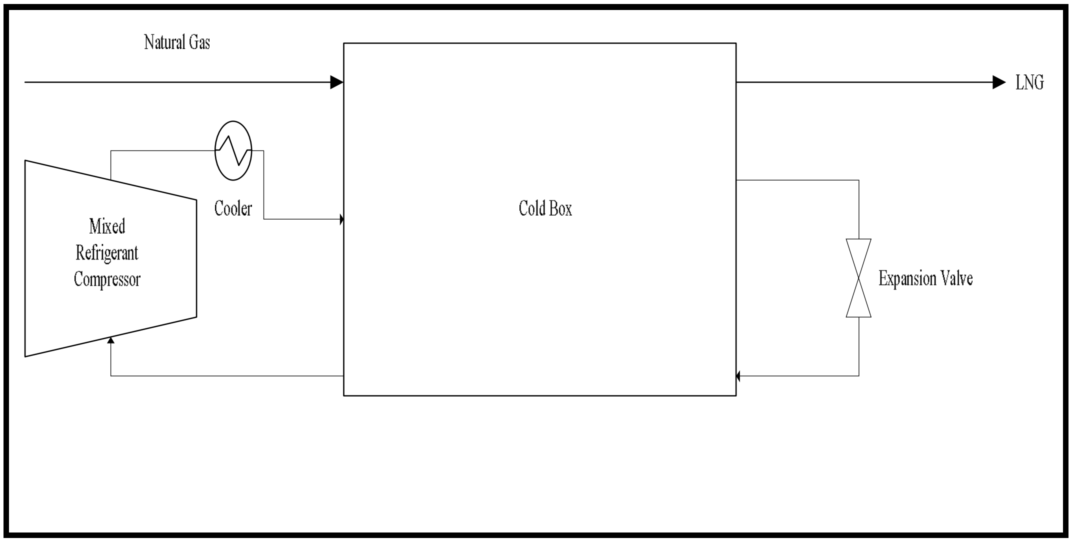

Figure 1.4: The Simplified Single Mixed Refrigerant Process (From Lee, 2000)

1.2.1.3 Propane Pre-cooled Mixed Refrigerant Process

The propane pre-cooled mixed refrigerant process, Figure 1.5, utilizes a mixed refrigerant (MR) that has a lower molecular weight and is composed of nitrogen, methane, ethane and propane. The natural gas feed is initially cooled by a separate propane chiller package to an intermediate temperature, about - 35°C (-31°F), at which the heavier components in the feed gas condense out and are sent to fractionation. The natural gas is then sent to the main heat exchanger, which is composed of a large number of small-diameter, spiral-wound tube bundles. These permit very close temperature approaches between the condensing and boiling streams. The MR refrigerant is partially condensed by the propane chiller before entering the cold box. The separate liquid and vapor streams are then chilled further before being flashed across Joule-Thompson valves that provide the cooling for the final gas liquefaction. Figure 1.5 shows The Propane Pre- cooled Mixed Refrigerant Process (From S. Mokhatab and Michael J.).

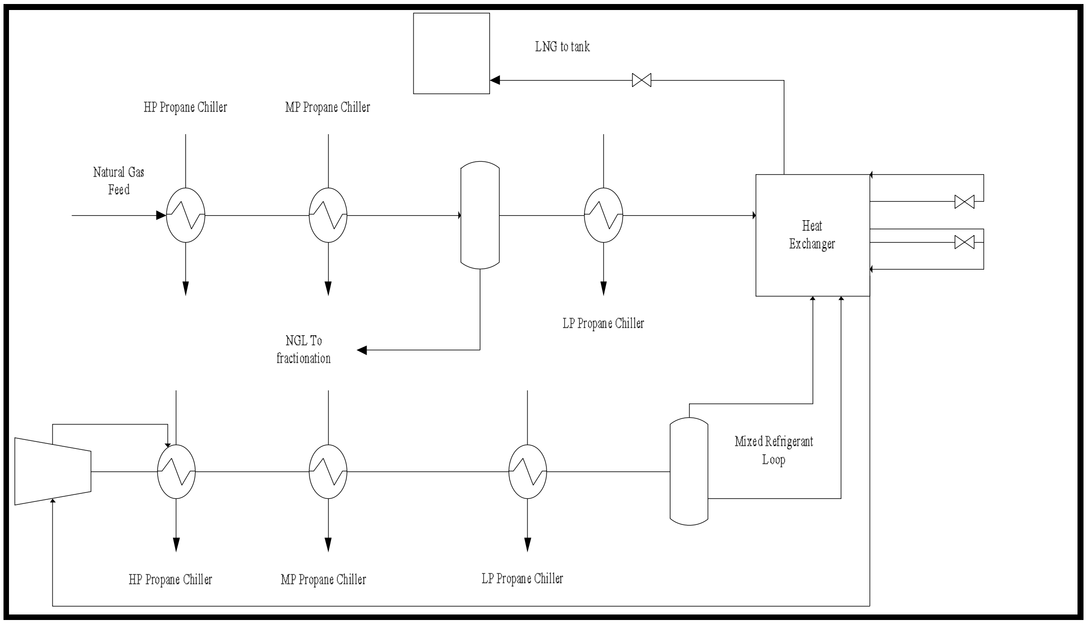

Figure 1.5: The Propane Pre-cooled Mixed Refrigerant Process (From S. Mokhatab and Michael J.)

1.2.1.4 Expansion Process

The expansions process expands natural gas from high pressure to low pressure with a corresponding reduction in temperature. As according to Joule-Thomson Effect, at which the expansion device such as turbo-expander, liquid turbine, and etc, must be adiabatic and reversible. It can be either isentropically or isenthalpically and operates on the principle that gas can be compressed to a selected pressure, cooled, and then allowed to expand. Figure 1.6 shows Simplified Expansion Process in LNG Production (From Barclay, 2005)

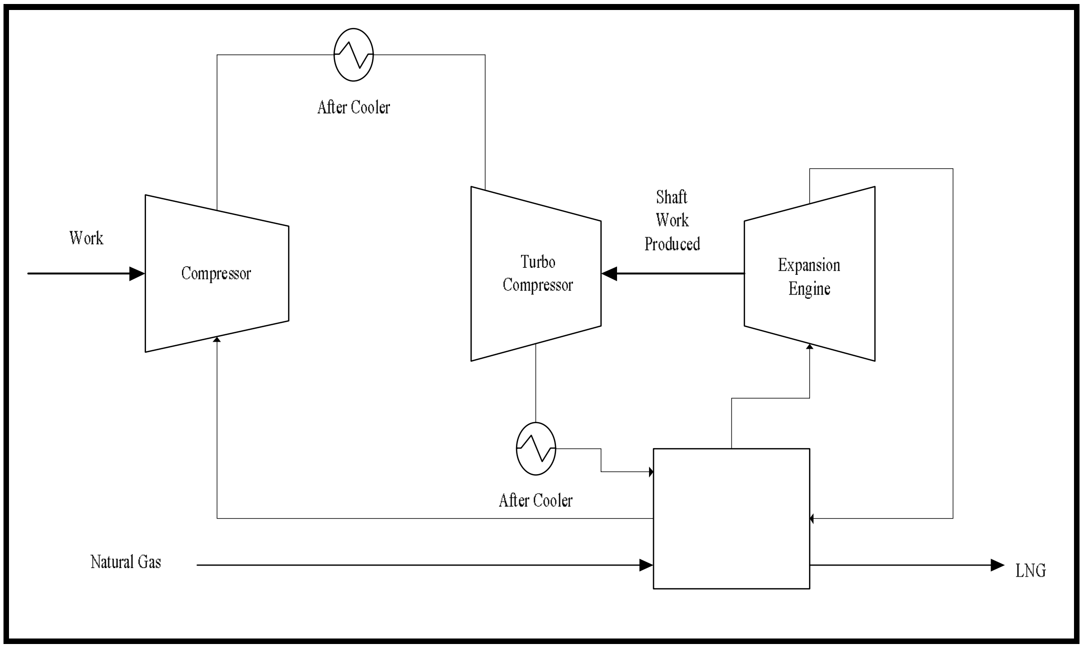

Figure 1.6: The Simplified Expansion Process in LNG Production (From Barclay, 2005)

1.3 LNG Cryogenic Plants

Natural gas liquefaction plants are generally classed as either peak-shaving or base-load plants depending on their size and role. These plants play an important role in order to deliver their annual capacity. The base load LNG plant usually use for marine (transcontinental) transportation. Nowadays, about 70 of base-load trains operating or under construction at 15 sites world wide and capable of producing from a single product line or train a capacity of up to 3.4 million tones per annum (Mtpa). In this type of plant, often two to three trains are installed to provide the required economies of scale. For the peak shaving plant, it facilities are usually small which is up to 0.9 million tones per annum (Mtpa). Peak shaving plant is also used to overcome mismatches between supply and demand. They liquefy and store excess natural gas during periods of low demand and vaporize it at times of peak demand (winter season). Besides above plants, other type of the LNG cryogenic plants is small scale plant. The opportunity of developing small scale natural gas liquefaction plants created from the continued commercial development of LNG vehicles. The markets for smaller-scale LNG liquefiers include onshore gas wells, customer sites that are remotely situated from current gas pipelines, and industrial customer peak shaving installations. Comparing with the medium-sized or large-scale liquefaction plant, the key characteristic of small-scale one are simple process, low investment, miniature size and skid-mounted package.

1.4 Techniques for Debottlenecking Process

Generally, bottleneck identification process can be classified into various types such as actual process performance and process experience. These methods involved the techniques of process simulation, hierarchical and heuristic which based on process experience, optimization which include a combination of process analysis and process synthesis, a two-stage debottlenecking process which combine the use of linear programming model at first stage followed by removal of bottlenecks, a developed algorithmic which applied to the retrofitting of an ammonia process and lastly, a combination between all these techniques. The most commonly used debottlenecking approach is the sequential method. In spite of its extensive usage, it is important to examine the ability of a sequential approach to attain the process true potential and in achieving maximum debottlenecking (Musaed, Nasser and Mahmoud, September, 2007). For this work, identification of the active bottleneck focuses on the techniques of process simulation using Aspen HYSYS simulator. Maximum debottlenecking can be achieved with the some development and alteration at the bottleneck conditions by applying the heuristic approach. As the bottleneck usually takes places in the equipments, then, evaluation in term of costing done based on the changing of the certain parameters.

1.5 Heat Transfer Equipment

In the process industries the transfer of heat between two fluids is generally done in heat exchangers. The most common type is one which the hot and cold fluids do not come into direct contact with each other but are separated by a tube wall or a flat or curved surface. The transfer of heat from the hot fluid to the wall or tube surface is accomplished by convection, through the tube wall or plate by conduction, and then by convection to the cold fluid.

Generally, shell and tube heat exchanger is used, which is the most important type of exchanger use in the process industries. In these exchangers the flows are continuous. Many tubes in parallel are used, where one fluid flows inside these tubes. The tubes, arranged in a bundle, are enclosed in a single shell and the other fluid flows outside the tubes in the shell side. The simplest shell and tube exchanger is shown in Figure 1.7(a) for one shell pass and one tube pass, or a 1-1 counter flow exchanger. The cold fluid enters and flows inside through all the tubes in parallel in one pass. The hot fluid enters at the other end and flows counter flow across the outside of the tubes. Cross baffles are used so that the fluid is forced to flow perpendicular across the tube bank rather than parallel with it. The added turbulence generated by this cross flow increases the shell side heat transfer coefficient.

In Figure 1.7(b), a 1-2 parallel counter flow exchanger is shown. The liquid on tube side flows in two passes as shown and the shell side liquid flows in one pass. In the first pass of the tube side, the cold fluid is flowing counter flow to the hot shell side fluid, in the second pass of tube side, the cold fluid flows in parallel (co-current) with the hot fluid. Another type of exchanger has two shell side passes and four tube passes. Other combinations of number of passes are also used sometimes, with the 1-2 and 2-4 types being the most common.